(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 October 2002 (24.10.2002)

PCT

(10) International Publication Number
WO 02/084375 A1

(51) International Patent Classification[7]: G02B 26/08, 5/18

(21) International Application Number: PCT/US02/09602

(22) International Filing Date: 27 March 2002 (27.03.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/832,699 10 April 2001 (10.04.2001) US

(71) Applicant: SILICON LIGHT MACHINES [US/US]; 385 Moffett Park Drive, Suite 115, Sunnyvale, CA 94089 (US).

(72) Inventor: AMM, David, T.; 178 Greenlees Drive, Kingston, Ontario K7K 695 (CA).

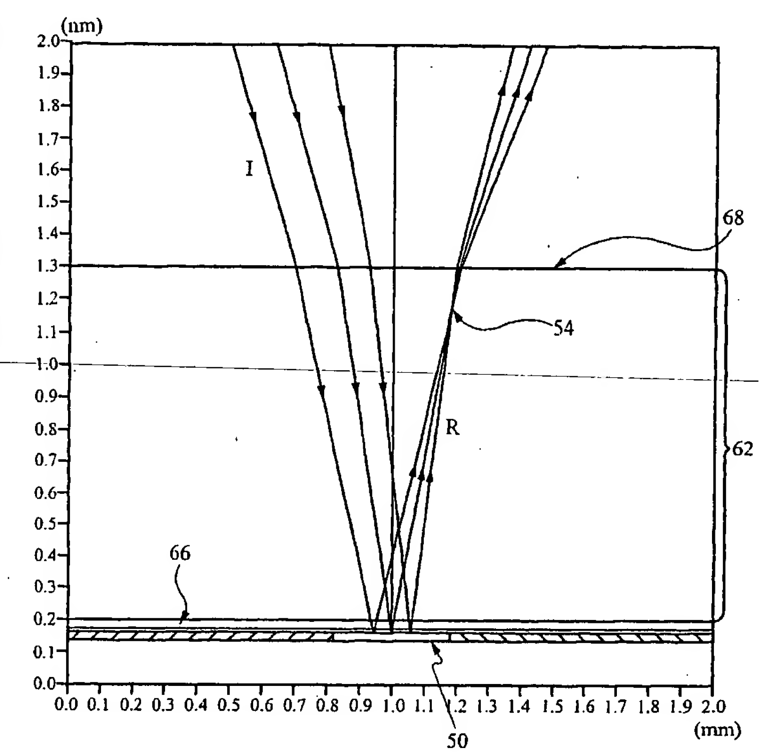
(74) Agents: HAVERSTOCK, Thomas, B. et al.; Haverstock & Owens LLP, 162 North Wolfe Road, Sunnyvale, CA 94086 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: MODULATION OF LIGHT OUT OF THE FOCAL PLANE IN A GLV BASED PROJECTION SYSTEM



(57) Abstract: A display apparatus projects an image onto a display screen and includes a grating light valve, a focusing arrangement and a scanning device. The grating light valve is located near but not at a focal plane of a line illumination such that in operation the grating light valve produces real or virtual two dimensional images. The grating light valve is configured such that the modular members on the surface of the grating light valve are neither parallel nor perpendicular to the effective pixel area, thereby arranged diagonally across the pixel area in order to eliminate any imperfections or defects in the line illumination. A seal glass is coupled with the grating light valve and forms an air gap between itself and the grating light valve such that the line illumination must pass through the seal glass and the air gap before reaching the grating light valve. Additionally, an absorbing aperture is affixed to the surface of the seal glass at the focal point of the illumination in order to further filter background light.

WO 02/084375 A1

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MODULATION OF LIGHT OUT OF THE FOCAL PLANE IN A GLV BASED PROJECTION SYSTEM

FIELD OF THE INVENTION

This invention relates to the field of image projectors. More particularly, this invention relates to the field of modulation of light out of the focal plan in a grating light valve based projection system.

BACKGROUND OF THE INVENTION

In recent years, light modulators have been developed using MEMS (micro-electro-mechanical systems) technology in which moveable elements are configurable to direct light. An example of such light modulators is a grating light valve (GLV) taught in U.S. Patent No. 5,311,360 to Bloom et al., in which the GLV is configurable in a reflecting mode and a diffracting mode. The GLV taught by Bloom et al. is isometrically illustrated in FIG. 1. The GLV 10 includes moveable elongated elements 12 suspended over a substrate 14.

A first side view of the GLV 10 of the prior art is illustrated in FIG. 2A, which shows the GLV 10 in the reflecting mode. The moveable elongated elements 12 each include a first reflective coating 16. Interspersed between the moveable elongated elements 12 are second reflective coatings 18. In the reflecting mode, upper surfaces of the first and second reflective coatings, 16 and 18, are separated by a height difference of a half wavelength $\lambda/2$ of incident light I. The incident light I reflecting from the second reflecting coatings 18 travels a full wavelength further than the incident light I reflecting form the first reflecting coatings 16. So the incident light I, reflecting from the first and second reflecting coatings, 16 and 18, constructively combines to form reflected light R. Thus, in the reflecting mode, the GLV 10 produces the reflected light R.

A second side view of the GLV 10 of the prior art is illustrated in FIG. 2B, which shows the GLV in the diffracting mode. To transition from the reflecting mode to the diffracting mode, an electrostatic potential between the moveable elongated elements 12 and the substrate 14 moves the moveable elongated elements 12 to contact the substrate 14. To maintain the diffracting mode, the electrostatic potential holds the moveable elongated elements 12 against the substrate 14. In the diffracting mode, the upper surfaces of the first and second reflective coatings, 16 and 18, are separated by a quarter wavelength $\lambda/4$ of the incident light I. The incident light I reflecting from the second reflecting surfaces 18 travels a half wavelength further than the incident light I reflecting from the first reflective coatings 16. So the incident light I, reflecting from the first and second reflecting coatings, 16 and 18, destructively interferes to produce diffraction. The diffraction includes a plus one diffraction order

D_{+1} and a minus one diffraction order D_{-1}. Thus, in the diffracting mode, the GLV 10 produces the plus one and minus one diffraction orders, D_{+1} and D_{-1}.

A first alternative GLV of the prior art is illustrated in FIGS. 3A and 3B. The first alternative GLV 10A includes first elongated elements 22 interdigitated with second elongated elements 23. The first elongated elements 22 include third reflective coatings 26; the second elongated elements 23 include fourth reflective coating 28. In the reflecting mode, illustrated in FIG. 3A, the third and fourth reflective coatings, 26 and 28, are maintained at the same height to produce the reflected light R. In the diffracting mode, illustrated in FIG. 3B, the first and second reflected coatings, 26 and 28, are separated by the second height difference of the quarter wavelength $\lambda/4$ of the incident light I to produce the diffraction including the plus one and minus one diffraction orders, D_{+1} and D_{-1}.

A display system utilizing a GLV is taught in U.S. Patent No. 5,982,553 to Bloom et al. The display system includes red, green, and blue lasers, a dichroic filter group, illumination optics, the GLV, Schlieren optics, projection optics, a scanning mirror, and display electronics, which project a color image onto a display screen. The red, green, and blue lasers, driven by the display electronics and coupled to the GLV (via the dichroic filter group and the illumination optics) sequentially illuminate the GLV with red, green, and blue illuminations. The GLV, driven by the display electronics, produces a linear array of pixels which changes with time in response to a signal from the display electronics, each pixel configured in the reflecting mode or the diffracting mode at a given instant in time. Thus, the GLV produces sequential linear arrays of red, green, and blue pixels with each of the red, green, and blue pixels in the reflecting mode or the diffracting mode.

The red, green, and blue pixels are then coupled to the Schlieren optics which blocks the reflecting mode and allows at least the plus one and minus one diffraction order, D_{+1} and D_{-1}, to pass the Schlieren optics. Thus, after passing the Schlieren optics, the linear arrays of the red, green, and blue pixels have light pixels corresponding to the pixels at the GLV in the diffracting mode and dark pixels corresponding to pixels at the GLV in the reflecting mode. The projection optics (via the scanning mirror) project the linear arrays of the red, green, and blue pixels onto the display screen while the scanning mirror, driven by the display electronics, scans the linear arrays of the red, green, and blue pixels across the display screen. Thus, the display system produces a two dimensional color image on the display screen.

A graphical top cross sectional view of a GLV is illustrated in FIG. 4. A scale in millimeters is provided to show an approximate layout of the system. In a system such as this, the GLV 10 is positioned such that the focal point 36 of the incident light I is located on the surface of the GLV 10. A seal glass 34 is positioned over the GLV 10 forming an air gap 32 between the GLV 10 and the seal glass 34. In this prior art embodiment, the seal glass 34 permits the incident light I to pass to the air gap 32 and

then to the GLV 10. The reflected light R travels through the air gap 32 and the seal glass 34 before a portion of the reflected light R is reflected by an outer surface 38 of the seal glass. As depicted in FIG. 4, this second reflected light R_2 eventually leaves the seal glass at a different point than the reflected light R. This second reflected light R_2, as well as additional reflected light derivative of R_2, creates undesirable background light in the final display.

An alternative display system utilizing the GLV includes the red, green, and blue lasers; red, green, and blue illumination optics; first, second, and third GLVs; the dichroic filter group; the projection optics; the scanning mirror; and the display electronics. The red, green, and blue lasers, via the red, green, and blue illumination optics, illuminate the first, second, and third GLVs, respectively. The first, second, and third GLVs produce the linear arrays of the red, green, and blue pixels, respectively, in response to signals from the display electronics. The dichroic filter group directs the light from the linear arrays of the red, green, and blue pixels to the Schlieren optics, which allows at least the plus one and minus one diffraction order, D_{+1} and D_{-1}, to pass the Schlieren optics. The projection optics, via the scanning mirror, project the linear arrays of the red, green, and blue pixels onto the display screen while the scanning mirror, driven by the display electronics, scans the linear arrays of the red, green, and blue pixels across the display screen. Thus, the alternative display system produces the two dimensional color image on the display screen.

Examples of applications for a GLV based display system include a home entertainment system, a boardroom application, and a cinema application among others. In the home entertainment system or the boardroom application, the GLV based display system projects the two dimensional color image onto the display screen located on a wall. In the cinema application, the GLV based display system projects the two dimensional color image from a display booth onto a cinema screen.

A GLV based display system may also be utilized in printing applications. In such a case, the system would not include a scanning mirror, and the printing media, replacing a screen, would move to effectuate printing from a fixed line of light.

What is needed is a method of reducing the problems of space, heat, noise, and vibration in the home entertainment system, the boardroom application, and the cinema application. The problem of heat in various applications affects the operation of the GLV and shortens the GLV's life span. Specifically, illumination intensity affects the operation of the GLV and ultimately shortens the GLV lifespan when a GLV is positioned at the focal plane of a line illumination. Typically, the optical focal point in a system such as this is at the GLV modulator, thereby exposing the GLV to high optical intensities anywhere from 50 Watts to 100 Watts per color. These intensities must be reduced in order to preserve the high quality function of the GLV over longer periods of time, thus extending the overall life span of the GLV. What is

also needed are methods for further correcting imperfections and defects in the line illumination that cause imperfections in the video display, while implementing an additional filtering step to eliminate more background light, thus further clarifying the display.

SUMMARY OF THE INVENTION

The present invention is a display apparatus and method for modulating light out of the focal plan in a grating light valve based projection system. The display apparatus and method includes positioning a grating light valve near but not at a focal plane of a line illumination such that the grating light valve produces either a two dimensional real image and a two dimensional virtual image.

The grating light valve in the present invention is also configured such that the modular members of the grating light valve are neither parallel nor perpendicular with the boundaries of the effective pixel area to broaden the width of the video line, thus correcting imperfections and striations attributable to ribbon defects. A seal glass is coupled with the grating light valve in such a manner that the line illumination must pass through the seal glass and an air gap between the seal glass and the grating light valve before reaching the grating light valve.

The present invention also embodies an absorbing aperture that is affixed to the outer surface of the seal glass at the focal plane of the line illumination in order to filter additional background light to achieve higher contrast, thus providing a much clearer picture.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an isometric view of a grating light valve (GLV) of the prior art.

FIG. 2 illustrates a side view of the GLV of the prior art.

FIG. 3 illustrates a side view of an alternative GLV of the prior art.

FIG. 4 illustrates a graphical top cross sectional view of a GLV of the prior art.

FIG. 5 schematically illustrates a display apparatus of the present invention.

FIG. 6 illustrates a plan view of display optics of the present invention.

FIG. 7 illustrates an elevation view of the display optics of the present invention with the display optics unfolded along an optical axis.

FIG. 8 illustrates a graphical top cross sectional view of the GLV of the preferred embodiment of the present invention.

FIG. 9 illustrates a front view of the GLV of an alternative embodiment of the present invention.

FIG. 10 illustrates a top view of a GLV system of an alternative embodiment of the present invention.

FIG. 11 illustrates a top view of a GLV system of an alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A display system of the present invention is illustrated schematically in FIG. 5. The display system 40 includes display optics 42 and display electronics 44. The display optics 42 comprise a laser 46, illumination optics 48, a grating light valve (GLV) 50, Schlieren optics 52, projection and scanning optics 56, and a display screen 58. The display electronics 44 are coupled to the laser source 46, the GLV 50, and the projection and scanning optics 56.

The display electronics 44 power the laser 46. The laser 46 emits a laser illumination. The illumination optics 48 focus the laser illumination onto the GLV 50. The GLV 50 is located in a first image plane 60. The display electronics 44 control the GLV 50. The GLV 50 modulates the laser illumination forming reflected light or diffracted light for a linear array of pixels. The Schlieren optics 52 separates the reflected light from the diffracted light allowing at least plus one and minus one diffraction orders to pass the Schlieren optics 52.

The display electronics 44 drive a scanning mirror of the projection and scanning optics 56. The projection and scanning optics 56 project the line image onto the display screen 58 and scan the line image across the display screen 58 to form a two dimensional image on the display screen 58. The display screen 58 is located in a third image plane 64.

The display optics 42 of the present invention are further illustrated in FIGS. 6 and 7. FIG. 6 illustrates a plan view of the display optics 42. FIG. 7 illustrates an elevation view of the display optics 42, with the display optics 42 unfolded along an optic axis 70. The laser 46 emits the laser illumination 72. The illumination optics comprise a divergent lens 74, a collimation lens 76, and a cylindrical lens 78. The illumination optics 48 focus the laser illumination 72 onto the GLV 50 in a focus line having a focus width. Note that FIG. 6 illustrates the laser illumination 72 illuminating the GLV 50 with an angle of incidence of 45°. Ideally, the angle of incidence is a minimum angle of incidence which allows the laser illumination 72 to illuminate the GLV 50 while allowing the reflected and diffracted light to reach the Schlieren optics 52. It will be readily apparent to one skilled in the art that other optics arrangements can be used to illuminate the GLV 50. It will also be readily apparent to one skilled in the art that depiction of lenses in the present invention is not limited to single component lenses and that any given lens can be replaced with a compound lens or a reflective optical element.

The GLV 50 modulates the laser illumination 72 as the linear array of pixels along the focus line, forming the reflected light R or the diffracted light, including the plus one and minus one diffraction orders, D_{+1} and D_{-1}, for each pixel. Preferably, the

GLV 50 produces a linear array of 1,080 pixels. Alternatively, the GLV 50 produces more or less than 1,080 pixels. Note that FIG. 7 illustrates the reflected light R and the plus one and minus one diffraction orders, D_{+1} and D_{-1}, for two pixels for illustration purposes. If a given pixel is modulated to reflect light, the reflected light R will be present and the plus one and minus one diffraction orders, D_{+1} and D_{-1}, will not be present. Alternatively, if the given pixel is modulated to diffract light, the plus one and minus one diffraction orders, D_{+1} and D_{-1}, will be present and the reflected light R will not be present. In some instances it is desirable to modulate the given pixel to produce the reflected light R and the plus one and minus one diffraction orders, D_{+1} and D_{-1}, in order to reduce a brightness of the given pixel in a resulting image, which provides a gray scale effect in the resulting image.

FIG. 8 is a graphical top cross sectional view of the GLV 50 of the preferred embodiment of the present invention. A scale in millimeters is provided to show an approximate layout of the system. Here, the GLV 50 is positioned such that the focal point 54 of the incident light I is near but not on the surface of the GLV 50. A seal glass 62 is positioned over the GLV 50 forming an air gap 66 between the GLV 50 and the seal glass 62. The seal glass 62 permits the incident light I to pass to the air gap 66 and to the GLV 50. In the preferred embodiment of the present invention, the GLV 50 is positioned such that the focal point 54 occurs beyond the surface of the GLV 50 as depicted in FIG. 8. After the incident light I reaches the GLV 50, the reflected light R travels through the air gap 66 and the seal glass 62 and into the Schlieren optics 52. The outer surface 68 of the seal glass 62 may further reflect a portion of the reflected light R producing unwanted background light. An additional remedy to this problem will be introduced in the alternative embodiment.

In the preferred embodiment of the present invention, the GLV 50 is positioned such that the focal point 54 is positioned at the outer surface 68 of the seal glass 62. It will be readily apparent to one skilled in the art that the arrangement of the GLV 50 and the seal glass 62 is not limited to the arrangement depicted in FIG. 8.

Referring back to FIG. 7, the Schlieren optics 52 include a Schlieren stop 80 located between first and second relay lenses, 82 and 84. The Schlieren stop 80 stops the reflected light R and allows the plus one and minus one diffraction orders, D_{+1} and D_{-1}, to pass the Schlieren stop 80. The Schlieren stop 80 is preferably located in a first transform plane 85. Alternatively, the Schlieren stop 80 is located near the first transform plane 85.

The projection and scanning optics 56 comprise a projection lens 86 and the scanning mirror 88. The projection lens 86, via the scanning mirror 88, projects the line image 90 onto the display screen 58. The projection lens 86 also reforms the wavefront having the spatial phase variation across the line image width 92 on the display screen 58. The scanning mirror 88 is preferably located at about a second transform plane 94.

The scanning mirror 88 moves with a first scan motion A and, thus, scans the line image 90 across the display screen 58 with a second scan motion B. Preferably, the first scan motion A is a sawtooth scan motion where a first part of a scan cycle illuminates the display screen 58 and a second part of the scan cycle returns the scanning mirror 88 back to a beginning of the scan cycle. By repeatedly scanning the line image 90 across the display screen 58, a two dimensional image is formed on the display screen 58. It will be readily apparent to one skilled in the art that other scan motions can be used to scan the line image 90 across the display screen 58. It will also be readily apparent to one skilled in the art that a transmissive scanning device such as an objective scanner having zero optical power can replace the scanning mirror 88.

As the line image 90 scans across the display screen 58, the GLV 50 modulates the linear array of pixels thus producing the two dimensional image made up of a rectangular array of pixels. For a high definition television (HDTV) format, the GLV 50 modulates 1,920 times as the line image 90 scans across the display screen 58. Thus, the GLV 50 preferably produces a 1,920 by 1,080 rectangular array forming the two dimensional image for the HDTV format. For other picture formats, the GLV 50 modulates more or less than the 1,920 times as the line image 90 scans across the display screen 58 depending upon which of the other picture formats is being displayed.

As the line image width 92 scans across the display screen 58, the wavefront having the spatial phase variation produces the multiple speckle patterns with time. The multiple speckle patterns reduce the speckle that is detected by the eye or the intensity detector of the optical system.

The display optics 42 depicted in FIGS. 5, 6, and 7 produce a monochrome image. Color display optics comprise the display optics 42, two additional lasers, two additional illumination optics, two additional GLV's, and a dichroic filter group. In the color display optics, red, green, and blue lasers illuminate the three GLV's producing red, green, and blue linear arrays of pixels. The dichroic filter group combines the reflected and diffracted light from the three GLV's and directs the reflected and diffracted light to the Schlieren optics 52. For the color display optics, the spatial phase variation across the line image width 92 preferably has an optimum amplitude for one of red, green, and blue laser illuminations (e.g., the green laser illumination), or a wavelength that is a specific average of participating wavelengths. The red, green, and blue wavefronts produce the multiple speckle patterns over time as the line image 90 is scanned across the display screen 58 and, thus, reduce the speckle in the color display optics. Alternatively, in the color display optics, the dichroic filter group combines the red, green, and blue laser illuminations to sequentially illuminate a single GLV.

Alternative embodiments of the present invention may include an angled GLV 96 as depicted in FIG. 9. Referring simultaneously to FIG. 6, FIG. 8, and FIG.9, the Schlieren optics 52 and scanning optics 56 must now use the focal point 54 as the object for projection, not the GLV 50 itself, in order to recover a square pixel. The moveable elongated elements 98 of an angled GLV 96 are positioned such that they are neither parallel nor perpendicular with the boundaries of the effective pixel area 100. This configuration of the moveable elongated elements 98 allows striations, artifacts or imperfections within the angled GLV 96 to be smeared out within the effective pixel area 100, rather than be dragged across the entire picture. This is particularly important for defects running the length of the ribbon such as ribbon bow tilt and deflection. By eliminating these problems within the effective pixel area 100, a softer picture is attained. Additionally, an angled GLV 96 reduces scanning defects and functions optimally with a wide illumination beam.

Another alternative embodiment of the present invention is depicted in FIGS. 10 & 11. In these two drawings, an absorbing aperture 102 is affixed to the outer surface 68 of the seal glass 62. The absorbing aperture 102 is fashioned such that it has an opening 104 where the focal point 54 meets the outer surface 68 of the seal glass 62. This alternative embodiment can be easily implemented in that it can be affixed away from the surface of the GLV 50 before the seal glass 62 is put in place above the GLV 50. This absorbing aperture 102 is implemented to block additional background light while allowing the reflected light R to pass to the Schlieren optics 52, thus improving the picture contrast and overall quality.

One modification to the preferred embodiment may include, but is not limited to, implementing a standard GLV rather than a blazed type. This modification can be implemented if throughput is not an issue, as in some printing applications. In which case, one of the diffraction orders would simply be ignored. Additionally, the technique in the preferred embodiment is also applicable to monochrome systems, since the single color would still be on-axis for the projection system.

It will be readily apparent to one skilled in the art that other various modifications may be made to the preferred embodiment without departing from the spirit and scope of the invention as defined by the appended claims.

CLAIMS

I claim:

1. A display apparatus comprising:
   a. a grating light valve located near but not at a focal plane of a line illumination such that in operation the grating light valve produces a linear image;
   b. a focusing arrangement coupled to the linear image; and
   c. a scanning device coupled to the linear image such that in operation the focusing arrangement and the scanning device produce a two dimensional image.

2. The display apparatus as claimed in Claim 1 wherein the two dimensional image is a real image.

3. The display apparatus as claimed in Claim1 wherein the two dimensional image is a virtual image.

4. The display apparatus as claimed in Claim 1 wherein the grating light valve is configured such that a plurality of modular members of the grating light valve are not parallel with respect to an effective pixel area of the line illumination.

5. The display apparatus as claimed in Claim 1 wherein the grating light valve is configured such that the plurality of modular members of the grating light valve are not perpendicular with respect to the effective pixel area of the line illumination.

6. The display apparatus as claimed in Claim 1 wherein a seal glass is coupled with the grating light valve such that the line illumination passes through the seal glass before reaching the grating light valve.

7. The display apparatus as claimed in Claim 6 wherein the seal glass is coupled with the grating light valve such that an air gap is formed between the seal glass and the grating light valve.

8. The display apparatus as claimed in Claim 6 wherein an absorbing aperture is affixed to a surface of the seal glass, said surface of the seal glass positioned at the focal plane of the line illumination.

9. A method of modulating light out of the focal plane in a grating light valve based projection system comprising:
   a. positioning a grating light valve near but not at a focal plane of a line illumination such that in operation the grating light valve produces a linear image;
   b. coupling a focusing arrangement to the linear image; and
   c. coupling a scanning device to the linear image such that in operation the focusing arrangement and the scanning device produce a two dimensional image.

10. The method as claimed in Claim 9 further comprising the two dimensional image being a real image.

11. The method as claimed in Claim 9 further comprising the two dimensional image being a virtual image.

12. The method as claimed in Claim 9 further comprising configuring the grating light valve such that a plurality of modular members of the grating light valve are not parallel with respect to an effective pixel area of the line illumination.

13. The method as claimed in Claim 9 further comprising configuring the grating light valve such that the plurality of modular members of the grating light valve are not perpendicular with respect to the effective pixel area of the line illumination.

14. The method as claimed in Claim 9 further comprising coupling a seal glass with the grating light valve such that the line illumination passes through the seal glass before reaching the grating light valve.

15. The method as claimed in Claim 14 further comprising coupling the seal glass with the grating light valve such that an air gap is formed between the seal glass and the grating light valve.

16. The method as claimed in Claim 14 further comprising affixing an absorbing aperture to a surface of the seal glass, said surface of the seal glass positioned at the focal plane of the line illumination.

17. A display system comprising:
    a. means for modulating light located near but not at a focal plane of a line illumination such that in operation the means for modulating produces a linear image;
    b. means for focusing coupled to the linear image; and
    c. means for scanning coupled to the linear image such that in operation the means for focusing and the means for scanning produce a two dimensional image.

18. The display system as claimed in Claim 17 wherein the two dimensional image is a real image.

19. The display system as claimed in Claim 17 wherein the two dimensional image is a virtual image.

20. The display system as claimed in Claim 17 wherein the means for modulating is configured such that a plurality of modular members of the means for modulating are not parallel with respect to an effective pixel area of the line illumination.

21. The display system as claimed in Claim 17 wherein the means for modulating is configured such that the plurality of modular members of the means for modulating are not perpendicular with respect to the effective pixel area of the line illumination.

22. The display system as claimed in Claim 17 further comprising means for sealing coupled with the means for modulating such that the line illumination passes through the means for sealing before reaching the means for modulating.

23. The display system as claimed in Claim 22 wherein the means for sealing is coupled with the means for modulating such that an air gap is formed between the means for sealing and the means for modulating.

24. The display system as claimed in Claim 22 further comprising means for absorbing affixed to a surface of the means for sealing, said surface of the means for sealing positioned at the focal plane of the line illumination.

25. A display apparatus for modulation of light out of the focal plane in a grating light valve based projection system comprising:

a. a grating light valve located near but not at a focal plane of a line illumination and configured such that a plurality of modular members of the grating light valve are neither parallel nor perpendicular with respect to an effective pixel area of the line illumination, said grating light valve positioned such that in operation the grating light valve produces a linear image;

b. a focusing arrangement coupled to the linear image;

c. a scanning device coupled to the linear image such that in operation the focusing arrangement and the scanning device produce a two dimensional image;

d. a seal glass coupled with the grating light valve such that the line illumination passes through the seal glass before reaching the grating light valve and such that an air gap is formed between the seal glass and the grating light valve; and

e. an absorbing aperture affixed to a surface of the seal glass, said surface of the seal glass positioned at the focal plane of the line illumination.

26. The display apparatus as claimed in Claim 25 wherein the two dimensional image is a real image.

27. The display apparatus as claimed in Claim25 wherein the two dimensional image is a virtual image.

28. A light valve comprising:

a. a light modulator configured to receive an illumination from an illumination source such that the illumination source is not focused on the light modulator; and

b. a focusing arrangement coupled to the illumination source such that the focusing arrangement focuses the illumination onto a target.

29. The light valve as claimed in Claim 28 wherein the focusing arrangement produces a two dimensional image, where the two dimensional image is a real image.

30. The light valve as claimed in Claim 28 wherein the focusing arrangement produces a two dimensional image, where the two dimensional image is a virtual image.

31. The light valve as claimed in Claim 28 wherein the light modulator is configured such that a plurality of modular members of the light modulator are not parallel with respect to an effective pixel area of the illumination.

32. The light valve as claimed in Claim 28 wherein the light modulator is configured such that the plurality of modular members of the light modulator are not perpendicular with respect to the effective pixel area of the illumination.

33. The light valve as claimed in Claim 28 wherein a seal glass is coupled with the light modulator such that the illumination passes through the seal glass before reaching the light modulator.

34. The light valve as claimed in Claim 33 wherein the seal glass is coupled with the light modulator such that an air gap is formed between the seal glass and the light modulator.

35. The light valve as claimed in Claim 33 wherein an absorbing aperture is affixed to a surface of the seal glass, said surface of the seal glass positioned at the focal plane of the illumination.

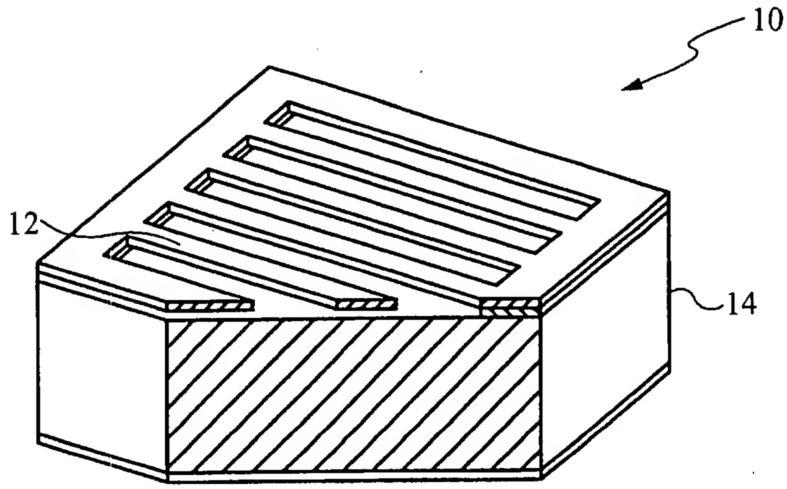


Fig. 1

(PRIOR ART)

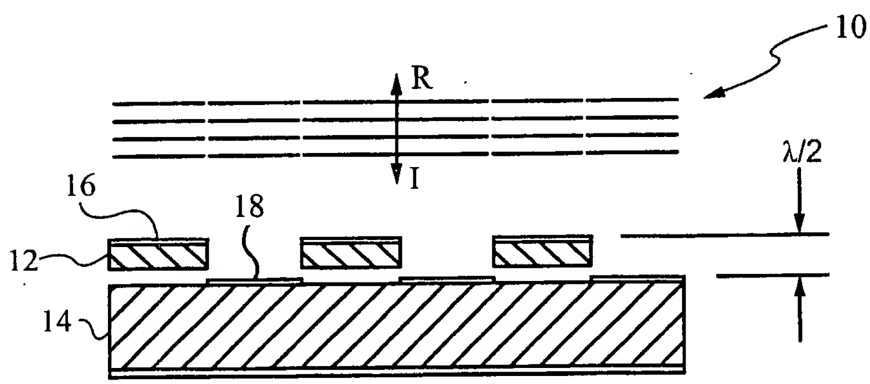


Fig. 2A

(PRIOR ART)

THIS PAGE BLANK (USPTO)

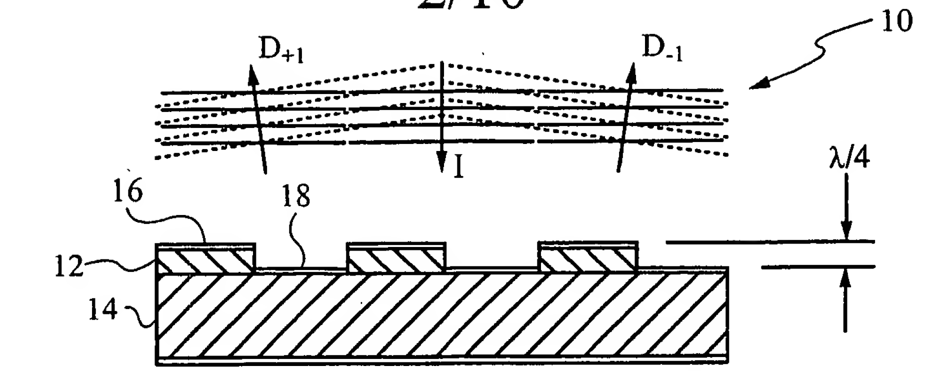


Fig. 2B

(PRIOR ART)

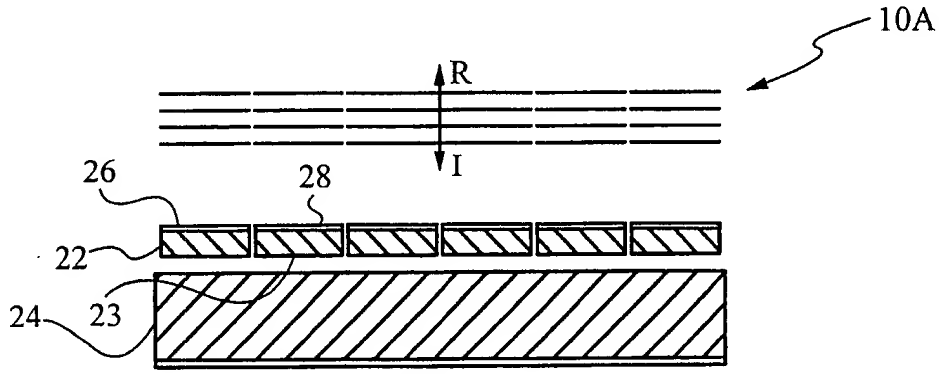


Fig. 3A

(PRIOR ART)

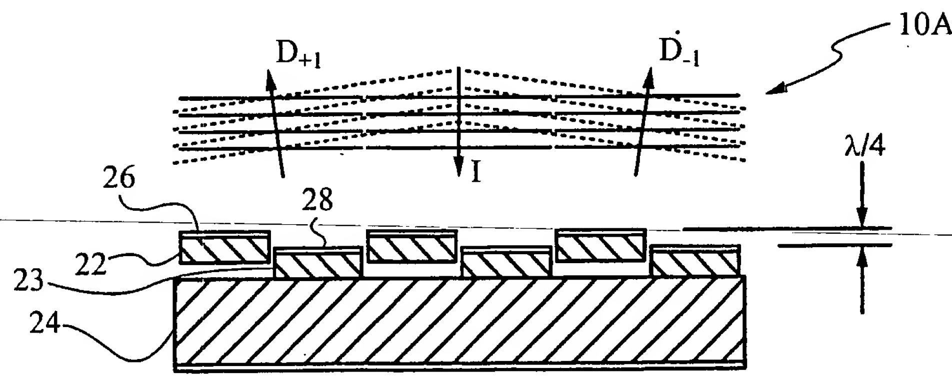


Fig. 3B

(PRIOR ART)

THIS PAGE BLANK (USPTO)

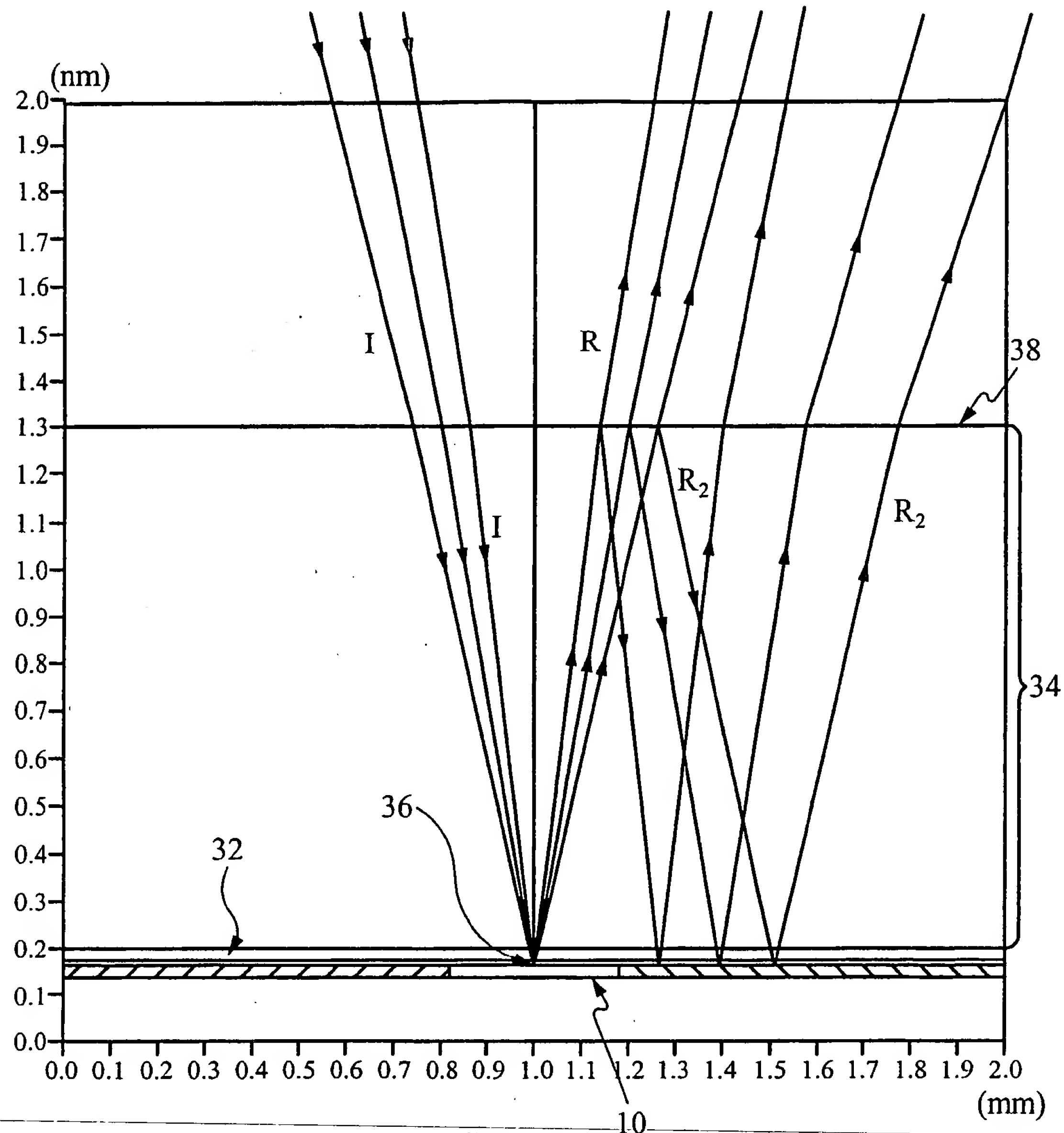


Fig. 4

(PRIOR ART)

THIS PAGE BLANK (USPTO)

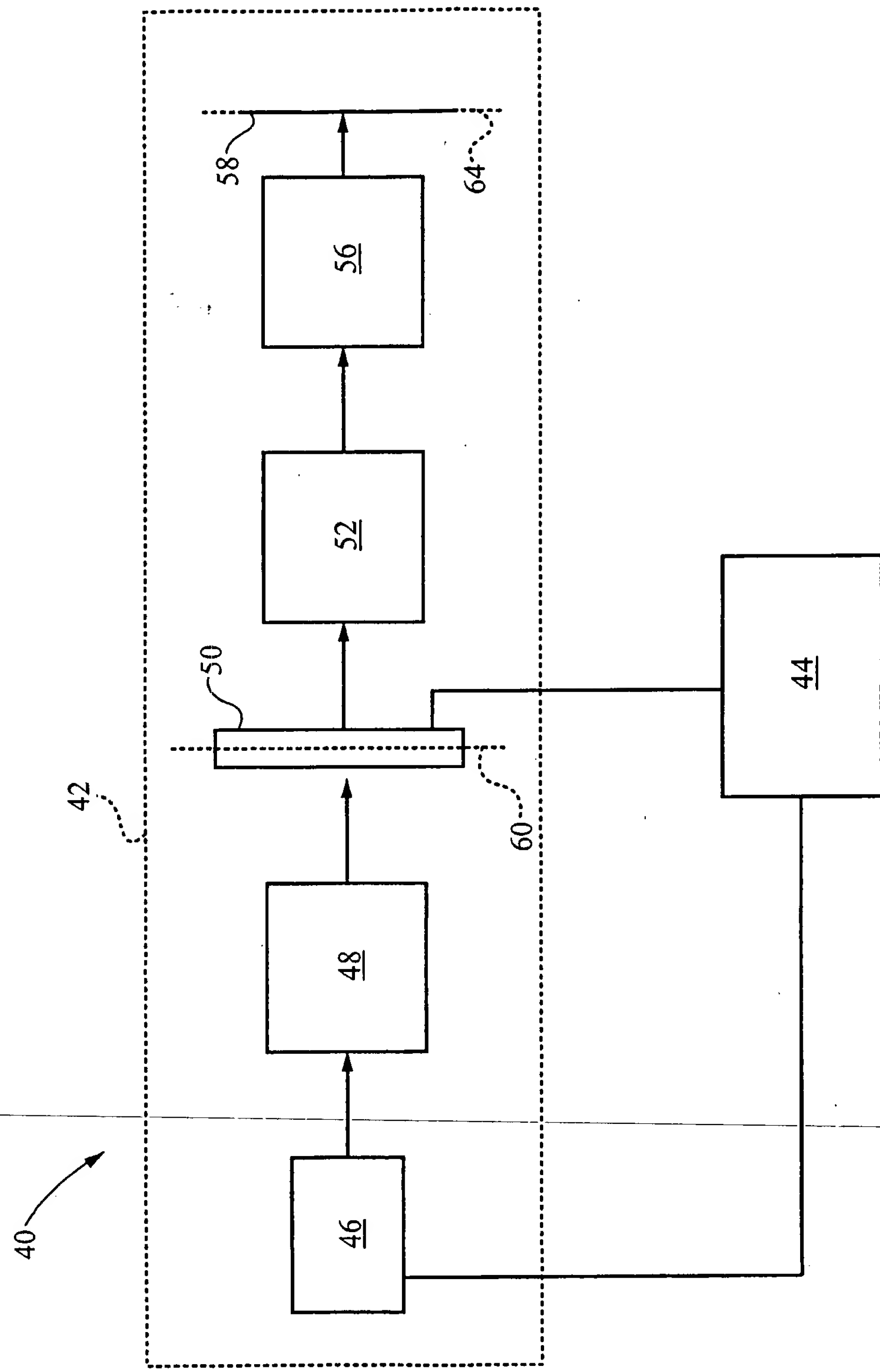


Fig. 5

THIS PAGE BLANK (USPTO)

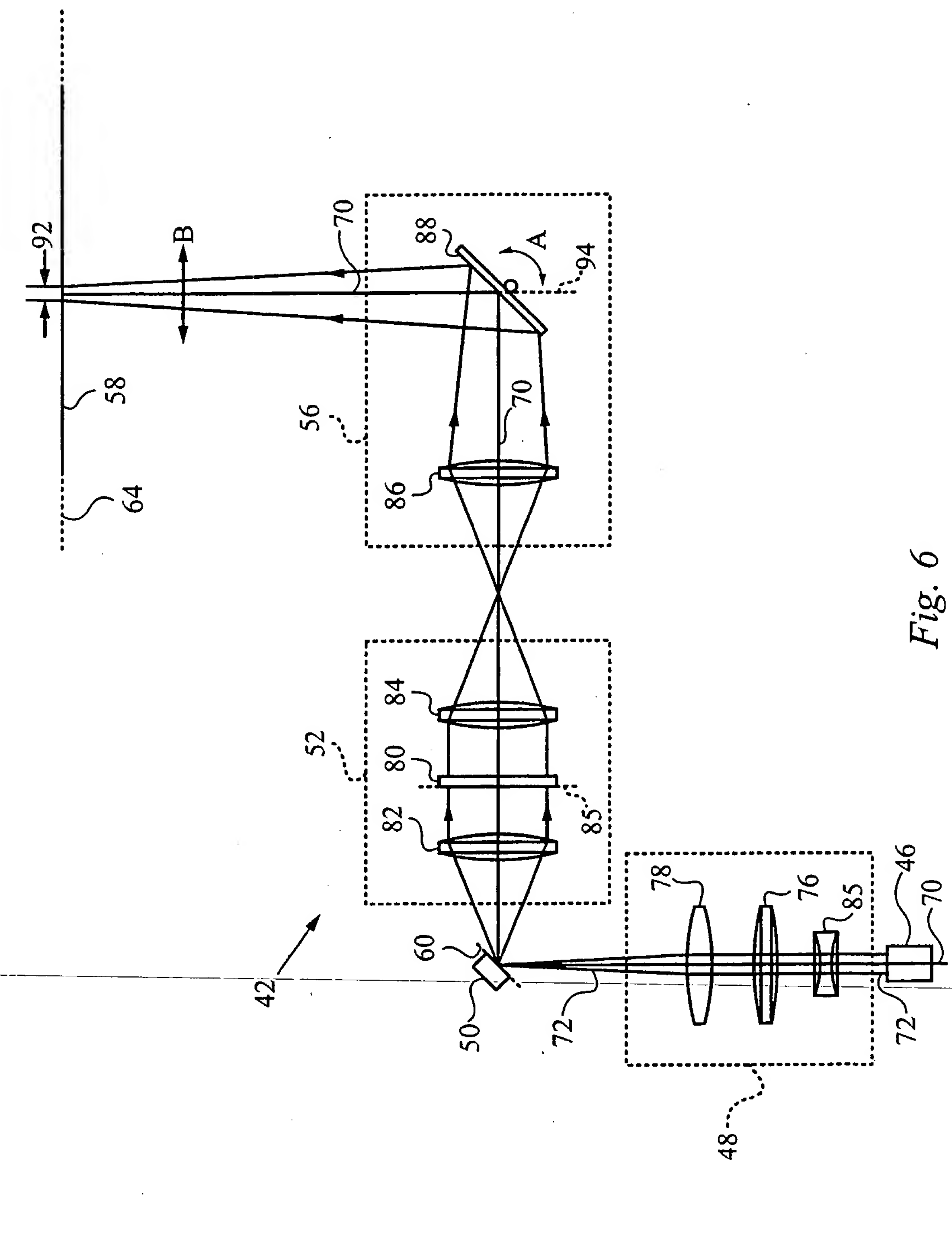

92
B
70
88
A
94
58
56
70
64
86
52
84
80
82
85
78
76
85
46
70
60
42
50
72
72
48

Fig. 6

THIS PAGE BLANK (USPTO)

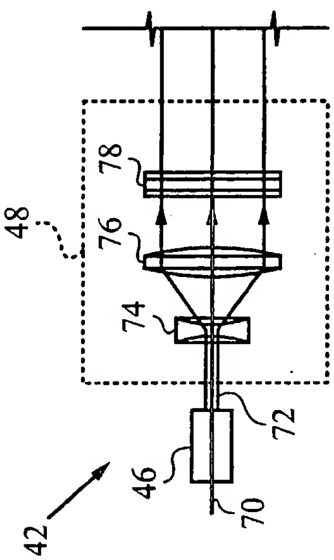


Fig. 7A

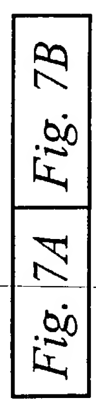


Fig. 7

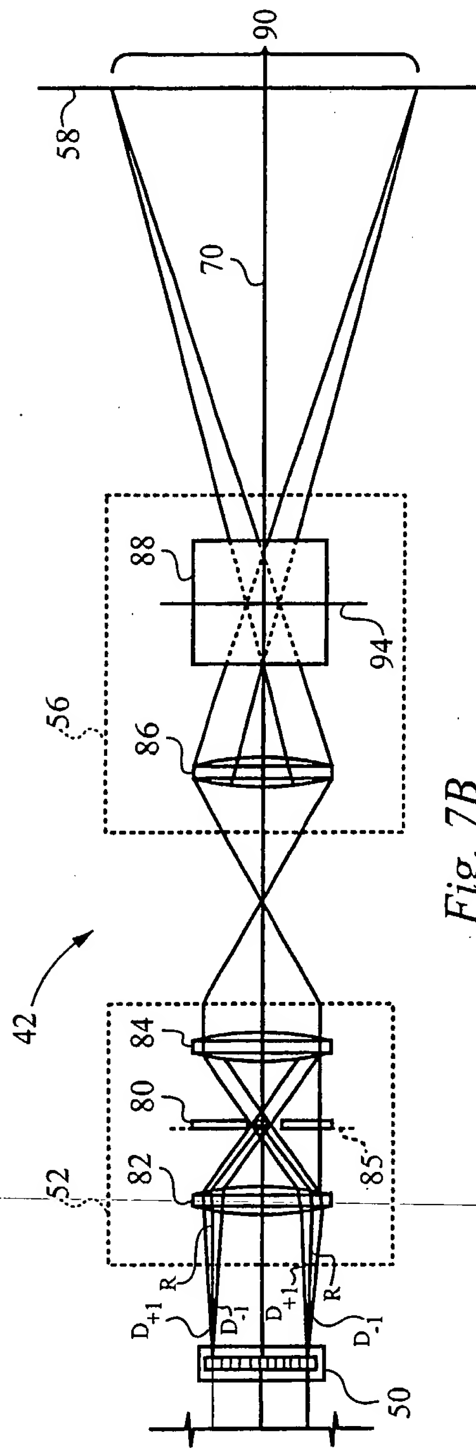


Fig. 7B

THIS PAGE BLANK (USPTO)

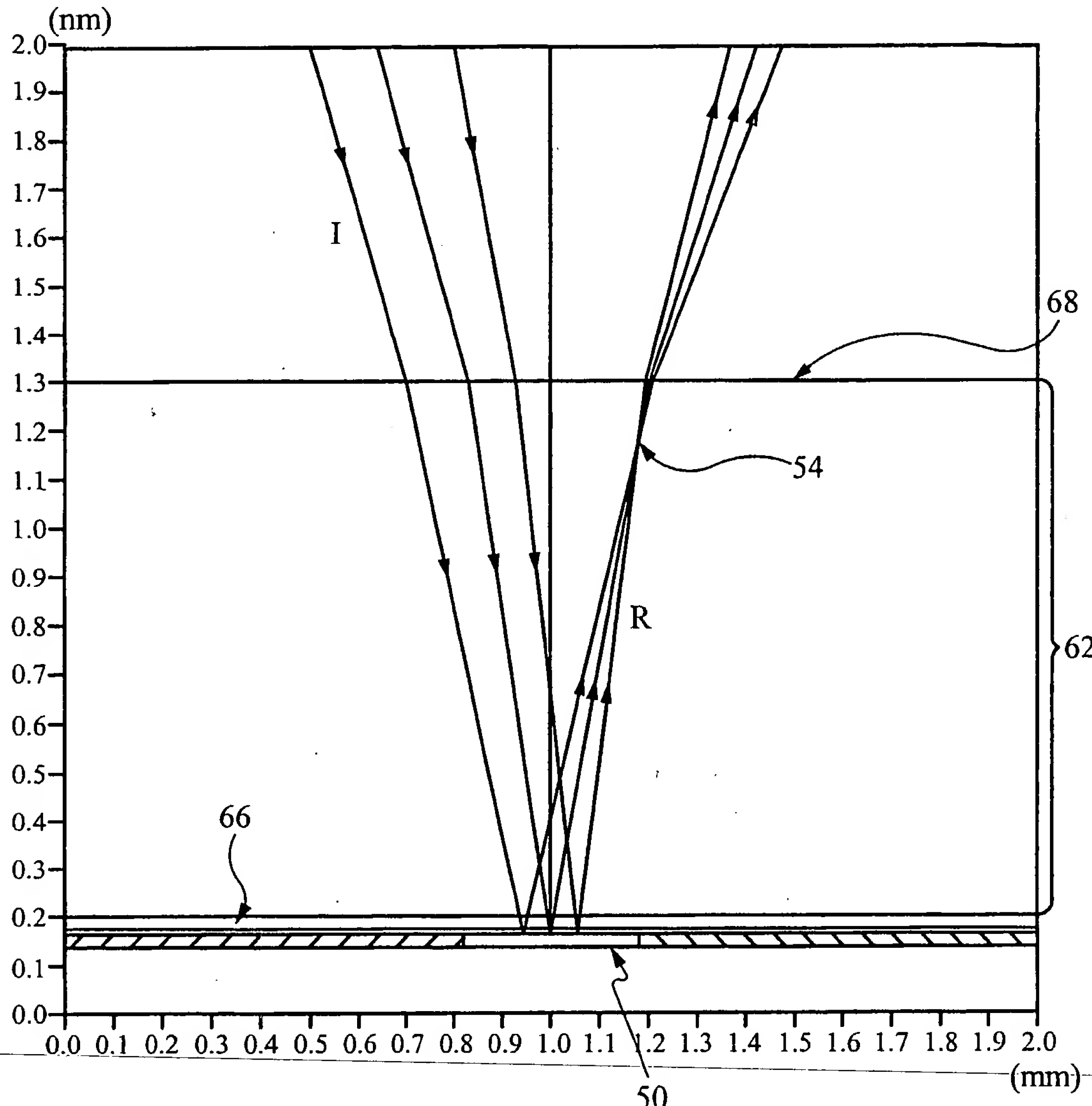

(nm)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
(mm)
I
R
68
54
62
66
50

Fig. 8

THIS PAGE BLANK (USPTO)

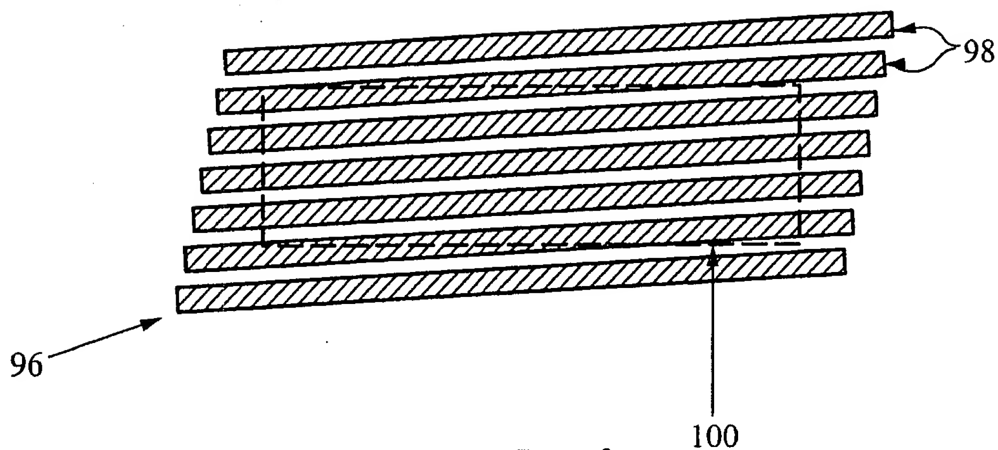


Fig. 9

THIS PAGE BLANK (USPTO)

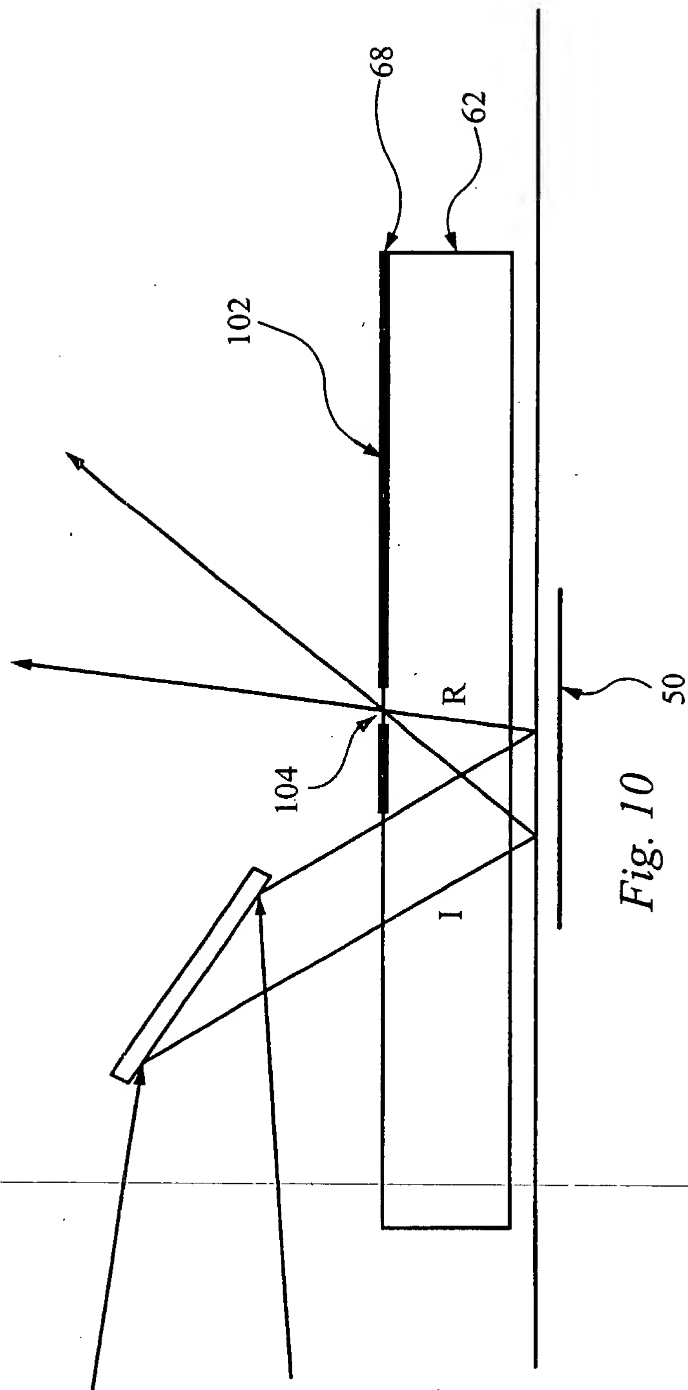


Fig. 10

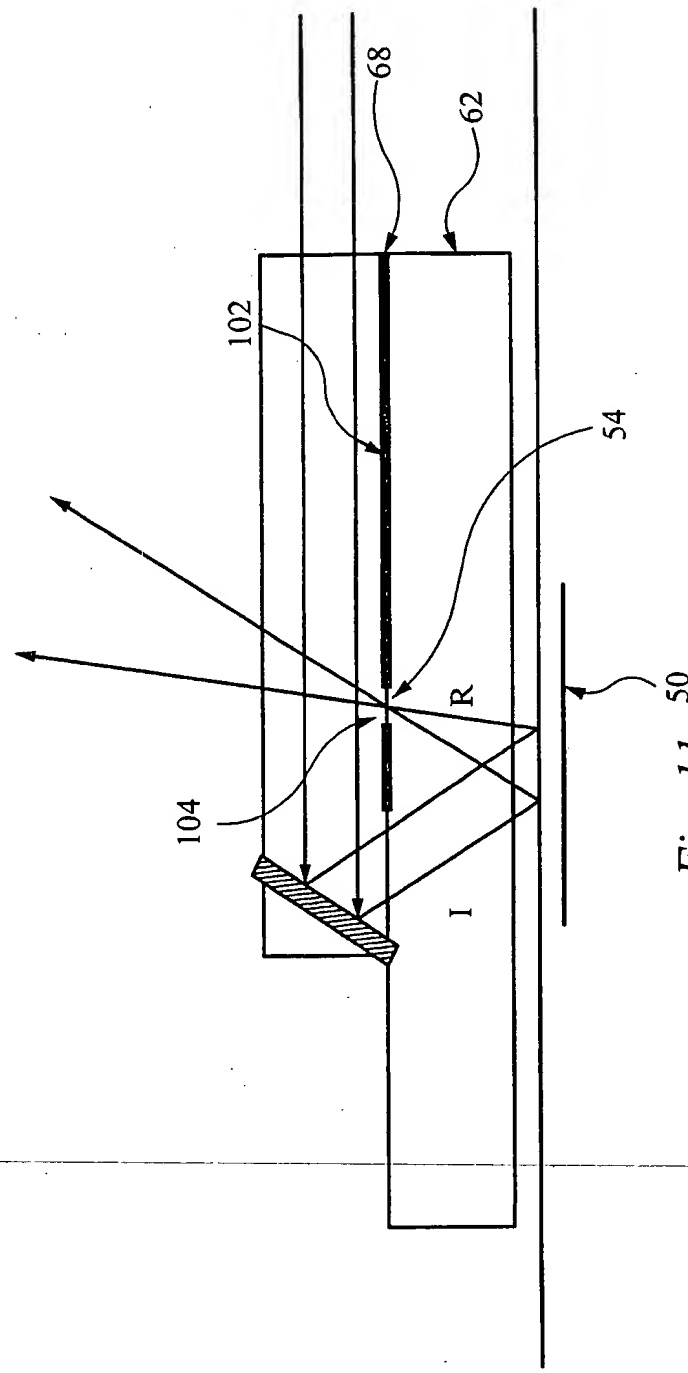


Fig. 11

THIS PAGE BLANK (USPTO)

INTERNATIC .L SEARCH REPORT

tional Application No
PCT/US 02/09602

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B26/08 G02B5/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 67671 A (SILICON LIGHT MACHINES INC) 29 December 1999 (1999-12-29) figures 14,15,17 page 1, line 6 - line 7 page 14, line 15 - line 21 page 12, line 23 -page 13, line 3 page 13, line 14 - line 15 page 16, line 24 - line 29 --- -/--	1-7, 9-15, 17-23, 28-34

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 August 2002	29/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Luck, W

THIS PAGE BLANK (USPTO)

INTERNATIC .L SEARCH REPORT

Information on patent family members

ıtional Application No

PCT/US 02/09602

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9967671	A	29-12-1999	US	6215579 B1	10-04-2001
			AU	4702199 A	10-01-2000
			CN	1313957 T	19-09-2001
			EP	1090322 A1	11-04-2001
			JP	2002519714 T	02-07-2002
			WO	9967671 A1	29-12-1999

THIS PAGE BLANK (USPTO)